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A More Sustainable Way to Treat School Furniture

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A More Sustainable Way to Treat School Furniture

by

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Abstract

Key Words: Sustainable, School, Furniture, Education

People start to aware of living in a sustainable life and used school furniture is a part of the waste. School is a learning environment, and students are not only learned from teachers but also anything around them. How schools treat school furniture can be a huge influence on student's attitudes to treat things in their lives. Therefore, this article is about how to redesign the school furniture sustainably and create an educational opportunity for students to learn how to live a sustainable lifestyle.

After the author analyses three aspects of the needs of school, manufacture, and sustainability and then conclude those three key features in the concept. Firstly, it is easy to repair. Keeps the product simple, eliminates complex components, and the user does not need an instruction manual to fix the product. Secondly, it needs to be strong and durable. Based on interviews and feedback from educational faculty, the school furniture must be strong because people will not be as gentle compared to using furniture at home. Thirdly, it can be disassembled. Accessibility to replacement parts is easy because of the design.

Based on those three features to develop the design that extends the life of the school furniture. The school can save the cost of furniture and also give a chance for students to learn to treat objects around them in a proper way.

Introduction

Why redesign school furniture? Furniture is an essential product in our lives, in the workplace, at home, at schools. How to properly deal with used furniture is a massive problem for our environment. Currently, school furniture is easily broken, and most of the components cannot be recycled. What if the furniture could last longer and then be recycled?

In my undergraduate career in Taiwan, I recall seeing piles of used school furniture abandoned in dark corners on campus, despite not being obsolete. That made me

realize how much waste could be generated by academic institutions. A research study in England showed that "approximately 700,000 tons of waste is being dumped to landfill from the educational sector alone. On average, each student generates 21kg of waste every year, and 72% of school waste is disposed of at landfill sites.'' [1] This shows that the issue of school waste is critical and cannot be ignored. Undoubtedly, used and redundant academic furniture represents a big part of school waste since academic institutions renew tens of thousands of used chairs and tables from time to time to provide a good learning environment. However, there is a way to provide a great learning environment without throwing out furniture, which is the primary goal of this project.

Schools are a big part of growing worldwide awareness of the need to strengthen environmental protection. An essay from Resource Smart Schools mentioned, "Education for sustainable development is a life-wide and life-long endeavor which challenges individuals, institutions, and societies to view tomorrow as a day that belongs to all of us, or it will not belong to anyone." [2] Moreover, schools have an essential role to play in preparing and empowering students to take responsibility for creating and enjoying a sustainable future. "Today, most kids are taught from a young age the value of "going green," the catchall phrase for protecting the environment. Thankfully, educators can launch the learning by merely pointing to the eco-friendly classroom furniture at students' fingertips." [3] The article mentioned that establishing sustainable furniture built around students is the best way to lead them towards a more sustainable life. Therefore, academic institutions must deal with furniture more sustainably properly.

Methodology

There are three main aspects to focus on the redesign of sustainable school furniture, manufacturing process, sustainability, and the requirement of school furniture.

1. Manufacturer

One of the faculty members told me that most of the school furniture is from Steelcase. Subsequently, I went to interview Ann Miller-Michaels, Sales & Marketing Manager of Steelcase. She told me that 99% of the components that make up their furniture could be recycled. Using the recyclable material to make products is one way to achieve sustainability, but is it the only way or best way to achieve it?

2. School

Take Rochester Institute of Technology as an example; interviews with school faculty shows that safety and quality are the essential requirements for school furniture.

Furthermore, according to the information from an interview with Kevin, who purchases school furniture, two parts of furniture are prone to be damaged. One is the seat of the chair, which has many scratches, and the edge is easy to chip off. Another one is the leg structure of the tables and chairs are not strong enough; for instance, if the legs are not well braced, they tend to loosen and break. Moreover, based on another interview with Tina Karol, a Senior Commodity Manager and Trademark Compliance at Rochester Institute of Technology, she said if the furniture gets damaged, they will call the company to recycle them. However, sometimes only parts of the furniture get damaged, such as the leg or the seat; other parts of the furniture still can be reused.

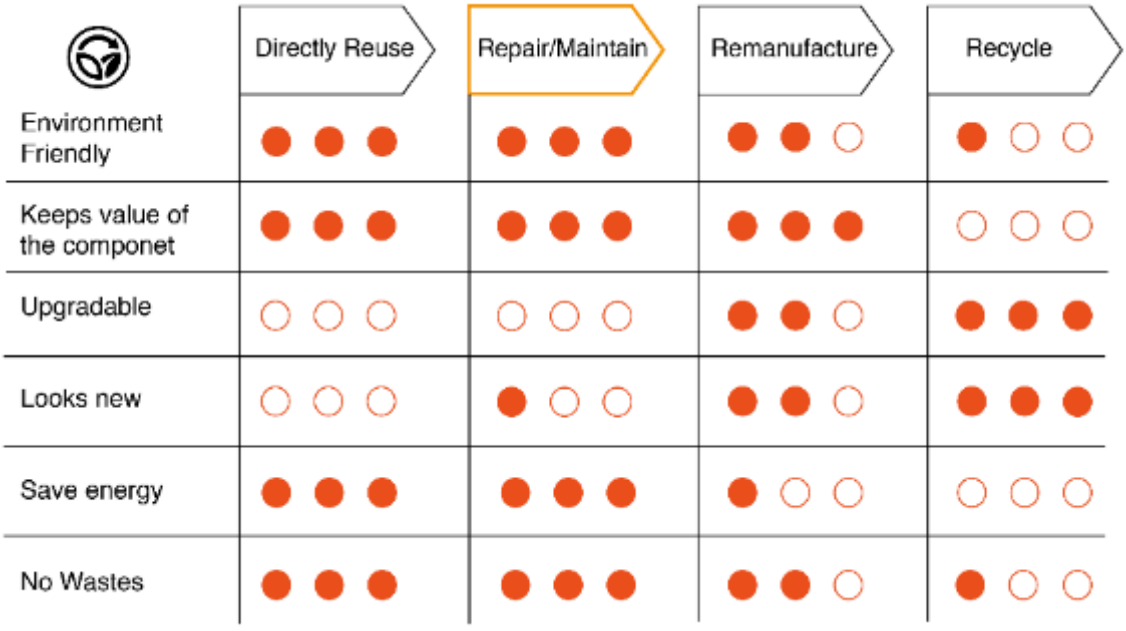
3. Sustainability

Like Proctor, Rebecca said in her book, "I believe that by manufacturing and consuming, it is possible to make sensible and inspiring choices, ultimately resulting in a positive effect on our environment." [5] This book talks about how sustainable

and design connects. In this book, the author selects many objects made in a sustainable way to show sustainable designs can bring a good impact on our lives.

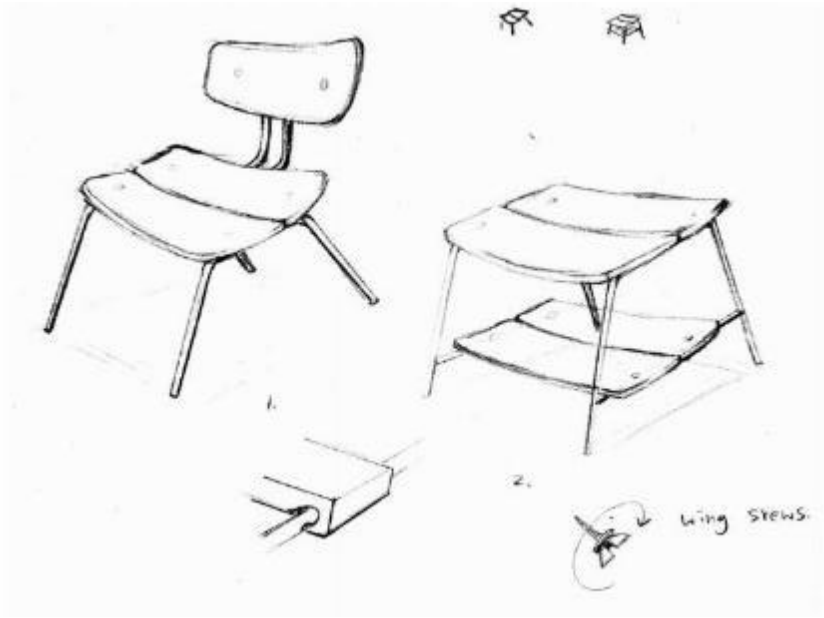
There are many ways to achieve sustainability. According to an interview with Jennifer, a Ph.D. student in sustainability, when the product reaches its end of life phase, the first thing to consider is whether it can be reused. This is the best outcome for the environment. If not, can it be repaired? Repairing is also good for the environment, but it does not upgrade the furniture, and it still looks old. The next question is, can it be remanufactured? Remanufacturing means keeping and using some components of old furniture. Many companies use this way to achieve sustainability because it provides an opportunity for renovation. The last question is, can it be recycled? This is also good for the environment, but it will waste energy to deal with the product and generate some scrap.

Reusing some components of furniture is more sustainable than directly recycling old furniture. Because recycling old furniture wastes energy, manufacturers usually disassemble the whole product into other products. Hence, I would like to design a way that people can quickly fix the broken parts of the furniture and then use it immediately, instead of waiting for the maintainer to fix the furniture.



The chart of sustainability is based on the interview result

Ideation



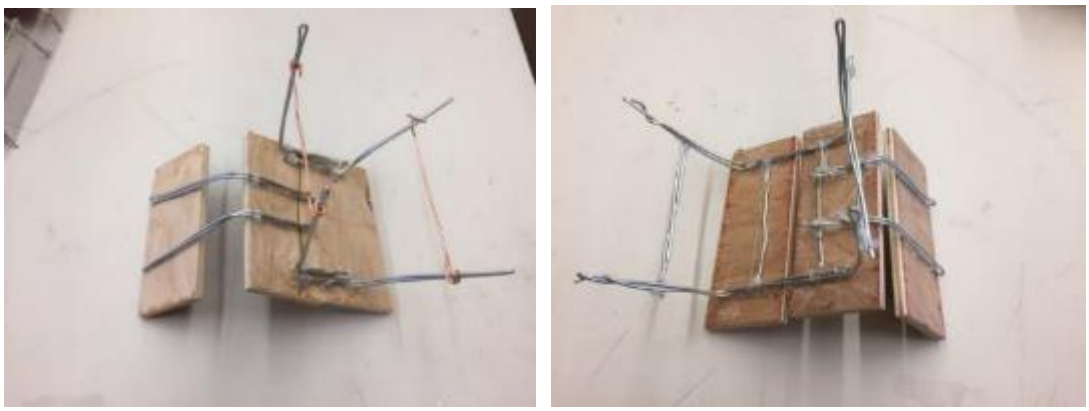
[Figure1]

In [Figure1], the seat and the backrest are the same units, which are the same size and same curve of the surface. As for the leg structure and the structure of the backrest support, they are using the same curve of the metal wireframe. Therefore, if one part of the seat is damaged, the user can replace it with the backrest component. However, if the leg structure is broken, the user can replace the broken part by the metal wire support of the backrest.

[Figure2] Wing head screws

For the connection of the chair, I have two ideas. One uses the wing head screws [Figure2] to connect all components, which the user can assemble by hand without

using power tools and screwdrivers. Another is the component having a curve like half of the circle, and the user can force it into the metal wireframe. In this design, the user can quickly fix the chair by using the same component of the chair.

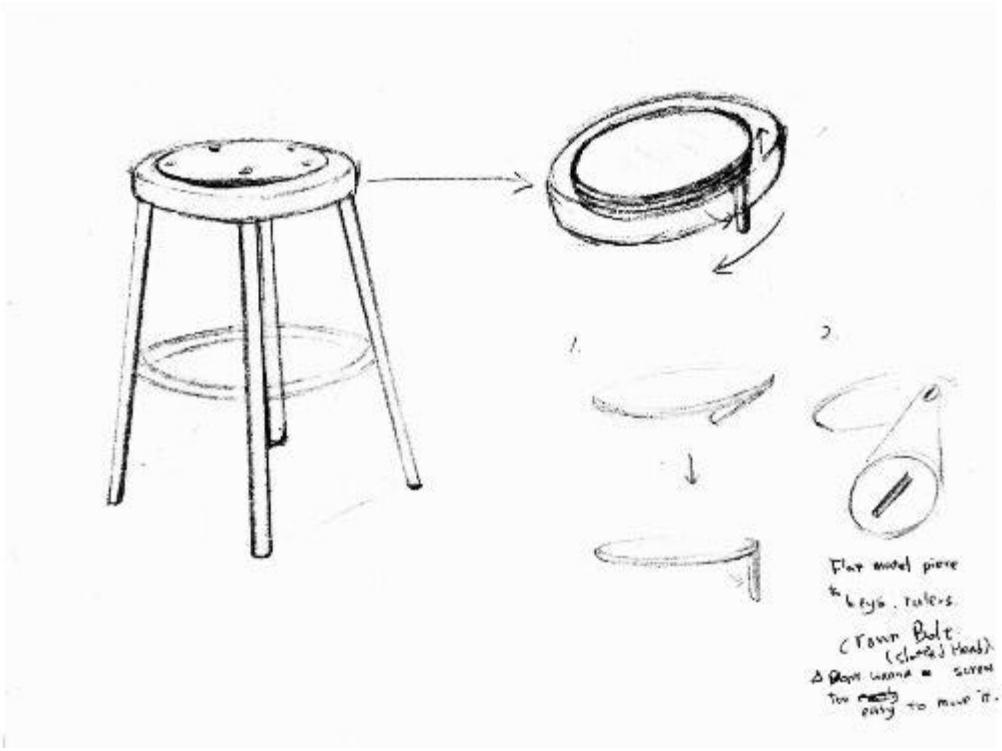


[Figure3] Testing the structure of the chair

By testing the structure of the chair, it needs to add two supports between two legs in order to make the structure stronger. Like the right one in the [Figure3]

[Figure4] Testing the structure

[Figure4] is testing that added the two boards under the seat for placing the bags, which can also strengthen the structure. This component is for connecting four legs. By using this structure can separate the pressure evenly form the seat.



[Figure5]

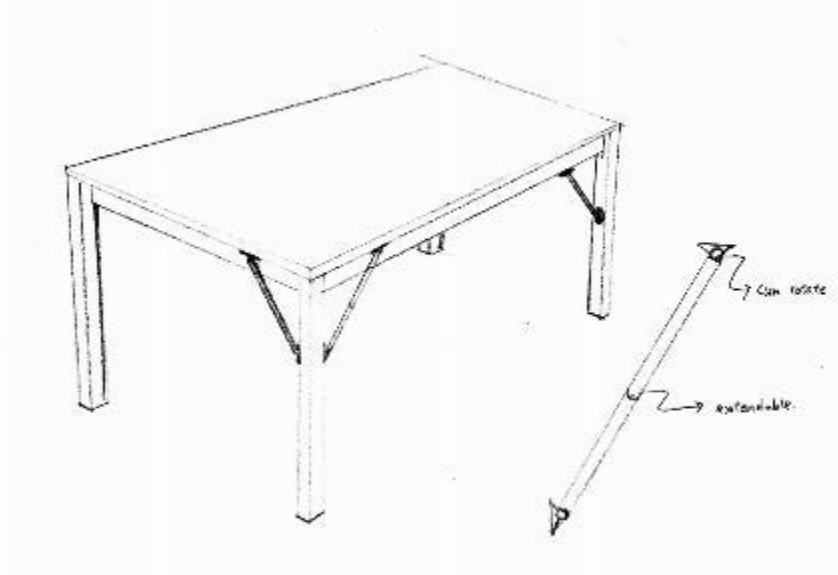
[Figure5] This design is for the user to change the seat by themselves. There are three layers inside the top of the seat; the bottom of the seat has a handle to roll it up. If the top one layer got damaged, the user could lift the layers to remove the old one and get a new one. I have designed two ways to lift the layers.

[Figure6] Slatted head of the screw

One uses a handle, and another places a slatted head of the screw[Figure6], and the user can use a flat metal piece like a key or a ruler to insert the screw and rotate the layer can prevent the user lift the seat by accidentally.

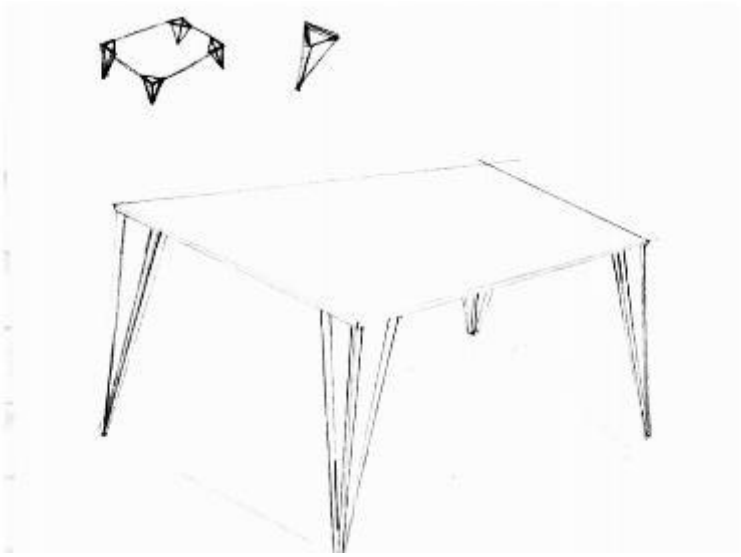
[Figure7]

In this design[Figure7], each leg has two metal wires connect with the seat, and this triangle structure is the strongest. Another feature is even one of the wires breaks that the chair still is stable.



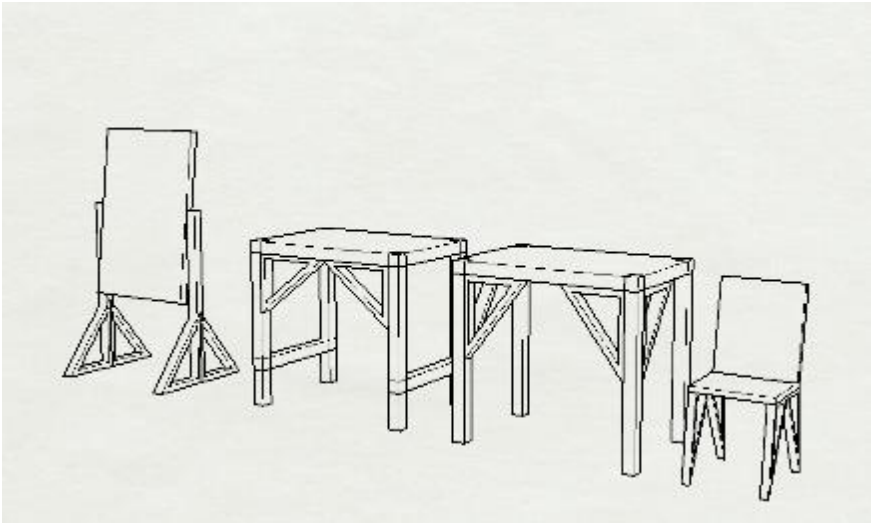
[Figure8]

This design[Figure8] is to fix the wobbling table, which is a common problem of school furniture. This is an extendable stick and has a rotatable cone on both sides that use to connect the leg and the tabletop to create a triangle structure for immediately solve the warbling issue.



[Figure10]

As I mentioned, the triangular structure is the strongest. Each leg has three wires connect with the top. This design can take longer the life of the table.



[Figure11]

It is using one component to adapt to a set of furniture. It can be a supporting structure of a table or the central support component of a board or the legs of a chair.

[Figure12] Testing structure

[Figure13]

Using dulls and form boards to make some small rough models figure out the most substantial furniture structure. [Figure12]

[Figure13] The result of this testing that the triangular shape is the strongest structure. This structure can adapt to all the furniture, so I apply this triangular structure on the leg.

Experiments

1. Making Model

Based on the information from the Ergonomic of the chair [6] as reference size to make the full-size model to test out the best dimension of the school furniture.

Legs: By using this structure, pressure can be distributed evenly throughout the seat.

[Figure 14] The first version of the testing seat

[Figure 15] The second version of the testing seat

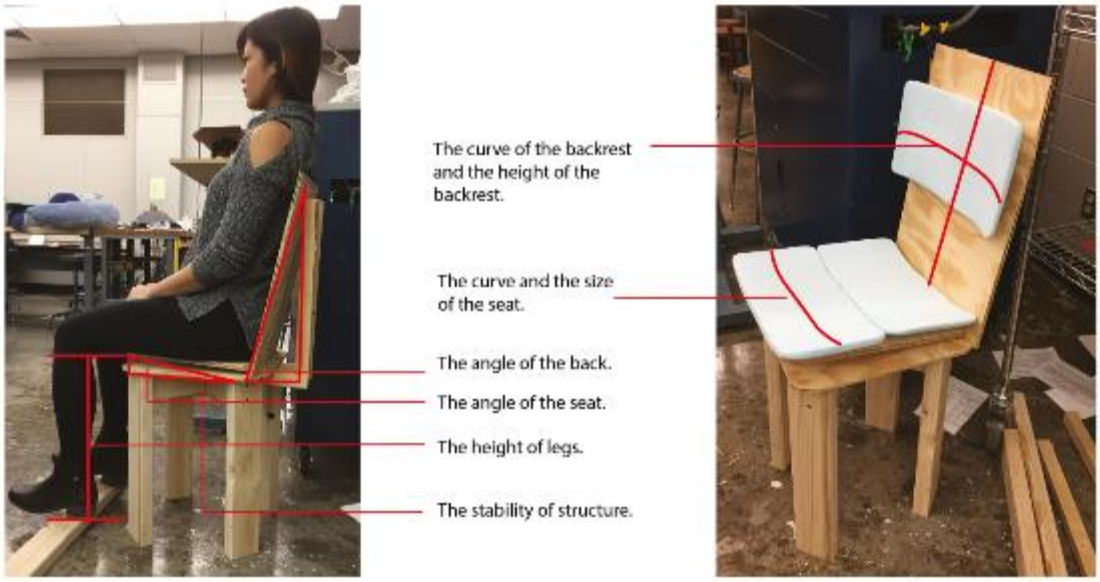
Seats: [Figure 14] The first version of the testing seat is broken during testing because people habitually press against the edge of the chair for support when they stand up. I use the second version of the testing seat [Figure 15] with the solid bottom for testing but keep the same cure and the size of it.

Wedges: Tring wedges of different height under the front board to find out the best angle.

2. Test the full-scale mockup

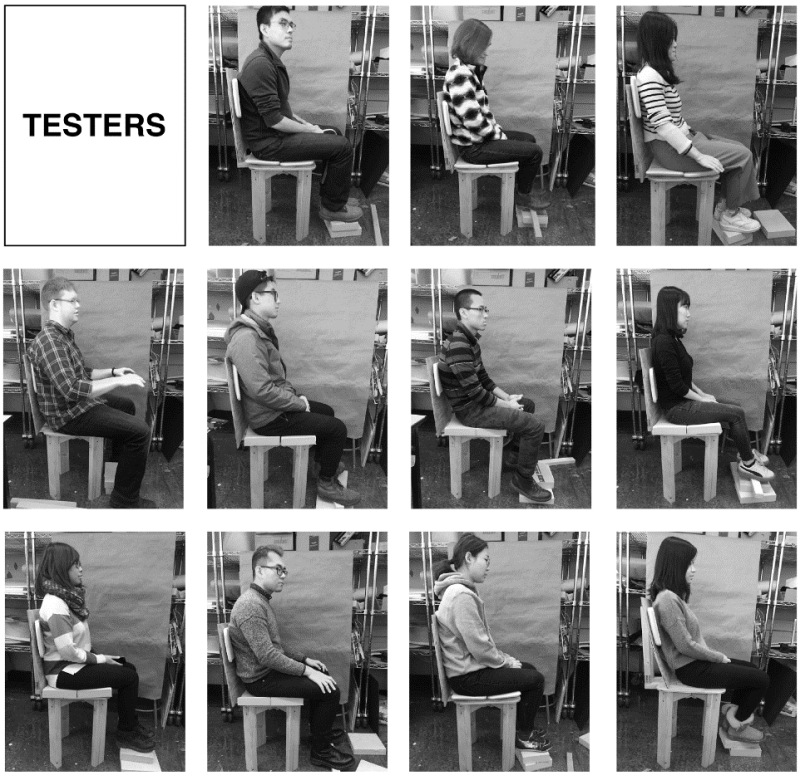
This test is to figure out these following items:

1. Back: The curve and height and angle of the backrest.
2. Seat: The curve and size, angle of the seats.
3. The height of the legs.
4. The stability of the structure.



3. Steps of testing the mockup

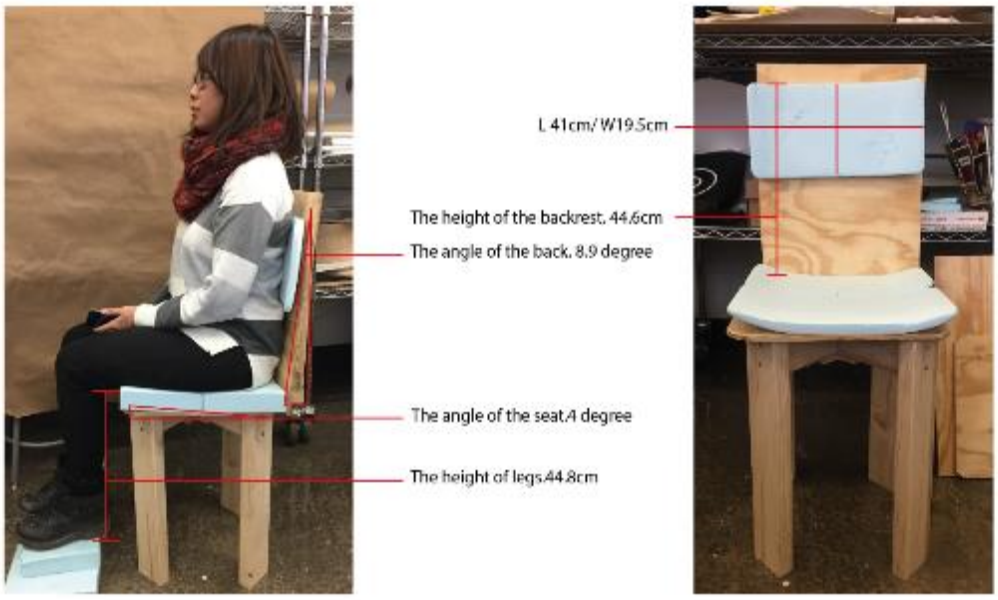
1. Tell tester to imagine themselves working with a laptop while sitting on the prototype.
2. Testing the angle of the backrest.
   The tester can move the board back and forth to find the most comfortable angle for them.
3. Testing the height of the backrest.
   Moving the panel up and down to find the optimal height to rest the back.
4. Testing the seat.
5. People sit on two panels made in the same cut to test their curve and the size.
6. A small wedge is then added under the first panel to tilt it five-degrees. The tester is then asked to sit on it again to feel the difference between a flat seat and an angled seat and then ask about which one is comfortable to sit.
7. Testing the structure of the legs.
   Ask the tester to shuffle on the prototype to test the stability of the structure.
8. Find out the best height of chair legs
9. Putting blocks of different height under their feet to find out the best height of chair legs.



4. Testing Result

After I invited twelve people to test this prototype, I took the average of the twelve data due to this test. The data are showing in Prototype testing1.0. [Figure19] Those data will be applying to this project.

Prototype Testing 1.0											
User name/ Height			Backrest				Seat			Leg	
			Curve	Height	Angle (5˚-15˚)	Size(19.5/41cm) (Depth/Width)	Curve	Angle (0˚-5˚)	Size(19.5/41cm) (Depth/Width)	Height (41-52cm)	Stability
1	Maggie	167	good	44.5	16	wider	good	Have angle	good	45	good
2	Doug	174	okay	46-49	7	okay	good	Have angle	good	45	okay
3	Liz	5'6	good	33	9	okay	good	Have angle	good	41.5	good
4	Yue	163	good	54	15	okay	good	Have angle	good	45.5	good
5	Kaining	170	good	31/45.5	6	deeper	good	Have angle	good	45	good
6	Evan	6'0	good	46	1	good	good	have angle	Wider	43	good
7	Stephen	5'8	good	48	1	good	good	0	good	44	good
8	Xiaoru	177	good	45.5	1	good	good	0	good	46	good
9	Phyllis	5'2"	good	39	15	good	good	Have angle	good	42	good
10	Peter	5'11"	good	46.5	12	good	good	0	good	48	good
11	Elmie	5'5"	good	43.5	16	good	good	Have angle	good	45	good
12	Limin	175	good	43	8	good	good	Have angle	good	48	good
Conclusion			**good**	**44.6**	**8.9**	**good**	**good**	**Have angle**	**good**	**44.8**	**good**



[Figure 16] The result of the test

5. Feedbacks from testers

Feedback from Stephen, the edge of the seat cuts into my thighs. As for this situation, I learned that the angle of the seat could not be too large, and the height of the legs cannot be higher than 50cm. Moreover, the other tester, Phyllis, suggests that the backrest could be moveable.

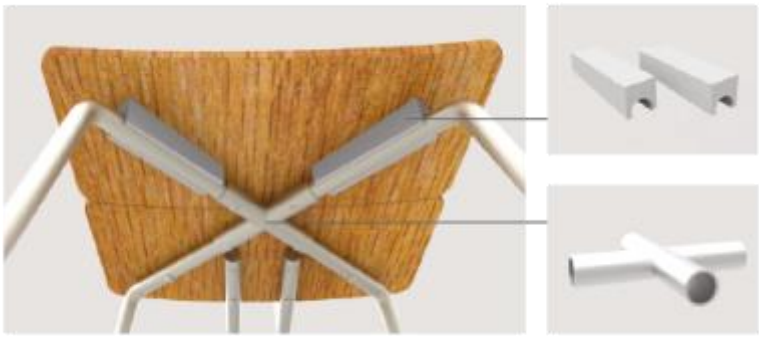
It indeed is a good idea, but not suitable for school furniture. More moving parts on a piece of furniture makes it easier to break. Liz, one of the testers, she breaks the form when she is testing the prototype. Because people habitually press against the edge of the chair for support when they stand up. The seat must be made in the hard material to avoid this situation.

Preliminary Design

1. The concept of the preliminary design

The seat and the backrests are the same cuts and the same size, curve of the surface. As for the structure of leg and backrest support, they are using the same curve of the metal wireframe.

Smoothing up the top of the edge of the backrest metal component for the student to hang their things, like bags or coats.



[Figure 17]

[Figure 18]

[Figure 17] These two components can adjust the height of the seat, which fits ergonomic and is more comfortable to sit on.
[Figure 18] This component is for connecting four legs. By using this structure, pressure can be distributed evenly throughout the seat.

2. Benefits

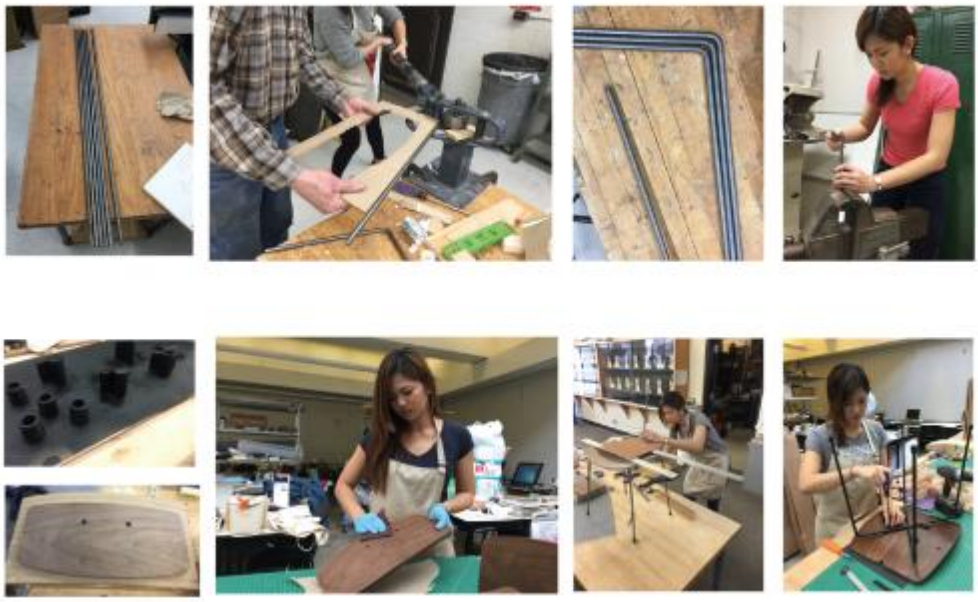
Therefore, if one part of the seat is damaged, the user can replace it with the backrest component for temporary use. Also, if the leg structure is broken, the user can replace the broken past by the metal component of the backrest.

Model making

For making the curve panel, which are the seat and the backrest components, using the MDF as a woodworking jig to ensure the curve of the seats are correct, and then utilize the vacuum bag system to press a couple of wood veneer together on the jig.

Take out the curve panel after 12 hours of waiting for the glue to dry out. Trim and sand the panel precisely to make all the panels are in the same size.

As for the metal structure, which is legs and backrest support components. Using a jig to make sure the angle is corrected, bend metal sticks to the right angle before welding the four legs together.



Final Design

After doing the project, I redesign the structure of the legs by welding them together instead use a metal component to connects four legs. Because of the safety concern, the structure is more robust when four legs are welded together as one piece. As for the wooden panels, I use two of them as the seat and one to be the backrest. All three of them are in the same cut, same shape, and same curve.

Conclusion

Based on the research, I chose the maintenance way to design sustainable furniture that will not waste energy remanufacture. Moreover, compared with other sustainable furniture on the market can be recycled, but it still consumes the energy for discomposing used products into raw material. In this design, it has two advantages, easily assemble, quickly fixed, comfortable transport.

First, all the connections can be easily assembled by using the screwdriver. Secondly, users can fix the broken part by themselves, like the wobbling legs or the broken edge of the seats. This design uses the same unit to assemble as the seat and backrest and use the same angle of the leg structure as the support of the backrest so users can replace the damaged component immediately.

From the manufacturing aspect, this product shortens the manufacturing process. This design only needs two molds for the manufacturing process; one is the metal wireframe; another is the board. Because these components are small and easily assemble, they can decrease the storage space. Furthermore, scales down the size of packages, which reduces the cost of the shipping.

For the school aspect, since the product is easily assembled, which is Flexibility-update to adapt the need of the school. Another benefit is that it reduces the cost of purchasing school furniture because it extends the lifetime of the product. As for the sustainability perspective, by using the maintenance way, this project reduces waste and carbon emission.

This design extends the life of the product to achieve a sustainable goal. However, in reality, the structure needs to be thoroughly tested. After all, durability is the most important function of the furniture and also for safety concerns. If this design success, then the next step will be to apply similar methods on the table to develop a set of sustainable school furniture.

References

1. Free School Furniture Disposal. "Free School Furniture Disposal." Accessed September 20, 2016. http://www.zooteducationalfurniture.co.uk/Free-School-Furniture-Disposal-Service.

2. Griffiths, Michele, Martin Richards, and Bob Winters. "How to Reduce, Reuse and Recycle Waste in Schools." Accessed September 20, 2016. http://www.sustainability.vic.gov.au/~/media/resources/documents/Services and advice/Schools/5Star Sustainability Certification/Waste Module/Waste Module resources/SV RS ReduceReuseRecycle1.pdf.

3. https://smithsystem.com/smithfiles/2013/09/01/what-makes-classroom-furniture-eco-friendly/

4. http://students.arch.utah.edu/courses/Arch4011/Recycling%20Facts1.pdf

5. Proctor Rebecca. The Sustainable Design Book. London: Laurence King, 2015.

6. Cornell University Ergonomics Web. "Sitting and Chair Design" http://ergo.human.cornell.edu/DEA3250Flipbook/DEA3250notes/sitting.html

[Figure 2] Wing head screws by Accu Product. https://www.accu.co.uk/en/wing-screws/67305-SWI-M6-30-A2?google_shopping=1&c=2&mkwid=sVWFFrypg&pcrid=184767276155&gclid=CLOovIuszdMCFcaKswodtAgN9w

[Figure 6] Slotted head of the screw by ASMC Industrial. https://www.asmc.net/3-x-3-4-wood-screw-slotted-round-head-brass-pk-100/?gclid=CI3184qtzdMCFRZMDQodNYEHVQ

Attachments

1. Interview questions

Interviewing with school faculty

1. What is the requirement of school furniture?
   (Like safety, durability, reasonable price, aesthetic, quality)
2. How often does school renew the school furniture?
   (What is the typical lifespan of school furniture?) (when do u decide to renew the furniture?)
3. What is the common reason to replace the furniture?
4. What is the procedure of renew the furniture?
   (What are the necessary steps to replace the old furniture? Research? Shop? Contact sales reps? Department budgets?)
5. How long does it take to complete the whole procedure?
6. Where do you purchase the furniture?
7. Where does those used furniture dispose of?
   (Where does the old furniture go?)
8. What is the cost (how much approximately) to replace furniture in an academic year?
9. How much budget for remove or disposal used furniture?
10. Was refurbished furniture ever being considered?
11. How likely is to refurbish existing furniture on campus instead of replacing with new ones?
12. Do you think there is anyone else I should talk to?

Interviewing with the Steel Case

1. How long have you working with RIT?
2. What is the difference between the office furniture and student furniture?
3. What kind of material are you used for furniture? Are those materials can be recycled?
4. Have you recycled some part of the used furniture?
5. Why the company can't recycle the whole furniture? Do you think recycle the whole used furniture is a possible thing?
6. Where does those used furniture dispose of?
7. Do you have any problem to deal with the used furniture?
8. What is the common reason to throw away the used furniture or some parts of it?
9. Kim mentioned about a company called DESK SET are refurbishing the used furniture. Can you tell me more detail about it?
10. Do you think there is anyone else I should talk to?

2. Ergonomic of the chair [6]

Seat Height - Optimum seat height is controversial.

Traditional Criterion - Seat height should be adjusted to support a knee angle of 90-degrees to prevent leg swelling. However, 75% of leg swelling may be due to low leg muscle activity rather than chair.

Minimum Height - should be 15" (38cm) which designs to the 5th percentile of women with 1" heels. The seat should adjust 9" (23cm).

Fixed Height - should be about 17" (43cm). This is a compromise. A chair that is too high leads to increased pressure at the popliteal fold (underside of knees), decreasing blood circulation and increasing pressure on the nerve. A chair that is too low increases weight on the ischial tuberosities.

Seat Pan -

Seat Depth - recommended is 16.5" for fixed seats and 14-18.5" for adjustable seats. If the seat depth is greater than the buttock-popliteal length (fifth percentile woman is at 17") then the user won't be able to use the backrest.

Seat Pan Contours - Half body weight is supported by an 8% area under the "seat bones" (ischial tuberosities). If the seat is hard and flat the pressures can be 85-100 p.s.i. Seat contouring and cushioning can be used to distribute pressure over a larger area and rotate the pelvis forward the promote better posture.

Seat Cushioning - recommended thickness at 1.5-2". Cushion should be firmer in back and thicker while less firm and thinner at front. Too much cushioning can cause the body to sink into a chair constraining movement. A soft chair may be comfortable at first, but as the body sinks blood circulation lowers, skin temperature rises in affected areas, and compression under thighs increases. These factors combine to increase discomfort.

Cushion Compressibility - Compressibility is termed indentation load deflection (ILD) or indentation force deflections (IFD). An ideal combination is a soft top layer (25% ILD) over a firm bottom layer (65% ILD). Increased ratios between the two, greater than 2.6, leads to better quality support.

Seat Width - around 20 - 22" to accommodate clothed persons. If seat has armrests, then elbow to elbow breadth may be more relevant.

Seat Angle - Positive seat angle helps user to maintain good contact with backrest. For most purposes a 5 - 10 angle is recommended.

Backrests -

Height - Higher backrests give better trunk weight support. Three categories:

Low-level backrest - supports the lumbar region only. Depth of the lumbar curve of the backrest should be 0.6 - 2.0". Backrest heights of 5, 7, and 9" seem equally effective.

Medium-level backrest - gives full shoulder support (e.g. car seat, office chair) and may need to be about 26" high to accommodate the 95th percentile man.

High-level backrest - full support of head and neck (e.g. plane seat) and may need to be about 36" for a 95th percentile man.

Angle - Optimal angle seems to be between 100-110-degrees.